

# **Final Technical Report**

**Project Title:** BlueFire Fulton Renewable Energy Project

**Award Number:** GO17025

**Recipient:** BlueFire Renewables

**Project Location:** Fulton, MS

**Principal Investigators:** Necy Sumait and John Cuzens

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## **Executive Summary**

BlueFire is proposing to construct an integrated commercial biorefinery in Fulton, Mississippi that will convert locally available cellulosic waste materials into ethanol, lignin, gypsum and animal feed (“Project”). Lignin produced will be used to provide the steam and electricity needs of the conversion process.

The award earned by the BlueFire under Section 932 of the Energy Policy Act of 2005 and American Reinvestment Recovery Act of 2009 of roughly \$88 million was bifurcated into two phases. This report describes the work accomplished and lessons learned under Phase 1 that positions the Project for detailed engineering and construction under Phase 2 of the award.

## **Planned Goals versus Actual Accomplishments**

The initial project award identified a Waste Management Landfill in Corona (El Sobrante) in Riverside County as the likely project site. Preliminary investigations and partner negotiations as well as community outreach were all positive. However, subsequent issues related to land contamination on the property was expected to need an extensive clean-up period jeopardizing the Project schedule.

After evaluating several sites in the area as well as feedstock sources for the project, a new site in the City of Mecca, still in Riverside County, and adjacent to a 47 Megawatt biomass power facility was proposed. Siting plans in conjunction with the power plant required consent from the Cabazon Band of Indians and that process was pursued. Work that was not site specific including a preliminary design basis document and process package was prepared with a local EPC contractor. Environmental evaluations were also started. However, the expensive process of going through an Environmental Impact analysis was deferred until the Cabazon transaction was resolved. Despite the interest the Cabazon expressed in completing site lease negotiations, the process continued to drag jeopardizing the development timeline. At about that time, BlueFire had already been looking at other sites that could be developed in a manageable timeline and so sites outside California were proposed with the preferred location being a site within an industrial park in the City of Fulton in Itawamba County, Mississippi.

Among other things, the Fulton site provided tri-modal access (rail, interstate and barge) which is very attractive for flexibility in the delivery of materials and shipment of products. Utilities including water, wastewater discharge, natural gas and electricity required minimal to no upgrade to accommodate the project. Also, the site is located within a radius where feedstock supplies would be available on a long term sustainable basis.

Upon approval by DOE of the Fulton site, work quickly commenced to complete key development milestones. Much of the baseline work already undertaken by the County of Itawamba facilitated the drafting of the NEPA document and completion of the EA process within an acceptable timeline.

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The Process Definition Package (PDP) had been proven previously with over 5,000 hours of pilot plant work accomplished at three different facilities in the U.S. and Japan. The preparation of the PDP for the Commercial Biorefinery proposed under the DOE grant required a process engineering firm of suitable size and commercial equipment vendors in the U.S. that would have to be sourced and trained as no commercial plant has yet been constructed.

A process engineering firm that had previous experience in starch ethanol production and sulfuric acid reconcentration was selected as the ideal firm for the task. U.S. equipment vendors who had participated in the initial U.S. pilot plant program years earlier were selected to repeat specific pilot tests in their own pilot plant equipment which they were comfortable scaling to commercial size quotations. This linear pilot demonstration involving equipment vendors was dubbed the Commercial Scaleup Program and resulted in the attainment of scaleup letters from all the major equipment packagers verifying their confidence in providing equipment systems scaled many times more than the 10:1 conventional equipment scaling factors for the commercial plant proposals. This testing was also administered by the (Engineering, Procurement, & Construction) EPC firm doing the PDP which provided for their deeper knowledge of the process dynamics.

Part of the PDP supporting the Front End Loaded (FEL-3) engineering and construction package being developed for the DOE facility would consist of commercial equipment specifications, data sheets, Process Flow Diagrams (PFDs), Process and Instrumentation Diagrams (P&IDs). Preliminary PDP documents were delivered by the initial EPC firm (Monsanto Environmental-Chemical Systems (MECS). This firm was acquired by Abengoa to form Abenics after starting the BlueFire work. The still to be completed PDP was transferred to a new EPC firm (Brinderson Corp) that had ample engineering staff and experience to complete the package and possibly perform the EPC contract for the DOE project.

The DOE Fulton FEL-3 work package was bid to several EPC contractors and a consortium of Wanzek Construction & Zachry Engineering and Construction was selected (Wanzek-Zachry) to become the FEL-3 contractor for the Fulton Project. The resulting package of 21 x 4-inch volumes of documents was so complete that Wanzek-Zachry offered to execute a full EPC contract for the project eliminating the need for bidding and selecting, if not training, a new EPC contractor for the Project saving monies and several months of schedule.

The FEL-3 package documents also provided the basis of environmental design needed to obtain the Project's Air, Water and Drainage permits to allow work to begin and preliminary construction documents to allow the bidding, award and completion of site rough grading, drainage and soil augmentation by the County after the permits were received as part of the Phase II work scope.

### *Planned Goals*

Task	Completion Date
Complete DOE Agreement	11/15/07
Sign PDP Engineering Firm	12/01/07
Confirm El Sobrante Site Selection	12/31/08
Complete CSP Test Program	6/30/08

Issue PDP Package	8/30/08
Design Package for Mecca Site	10/31/09
Confirm Mecca Site Selection	12/31/09
Complete PDP Fulton	3/31/10
Select EPC for FEL-3 Work	3/31/10
Confirm Fulton Site Selection	6/30/10
Sign Ethanol Takeout Agreement	7/1/10
Sign Feedstock Supply Agreement	7/1/10
Receive Fulton Permits	9/30/10
Complete FEL-3 Pkg.	9/30/10
Sign EPC	10/1/10

## Actual Results

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Description	Jun-09	Jul-09	Aug-09	Sep-09	Oct-09	Nov-09	Dec-09	Jan-10	Feb-10	Mar-10	Apr-10	May-10
Confirm Fulton Site Selctn	In Progress	In Progress	In Progress	In Progress	In Progress	In Progress	In Progress	Completed	Completed	Pending	Pending	Pending
Design Pkg for Fulton Site	Pending	Pending	Pending	Pending	Pending	Pending	In Progress	In Progress	In Progress	In Progress	In Progress	In Progress
Complete PDP Fulton	In Progress	In Progress	In Progress	In Progress	In Progress	Completed	Completed	Pending	Pending	Pending	Pending	Pending
Select EPC for FEL-3 Wrk	Pending	Pending	Pending	Pending	In Progress	Completed	Completed	Pending	Pending	Pending	Pending	Pending

Receive Fulton Permits												
Complete FEL-3 Pkg												
Sign Etoh Contract												
Sign Feedstock Supply Contract												

Description	Jun-10	Jul-10	Aug-10	Sep-10	Oct-10	Nov-10	Dec-10	Jan-11	Feb-11	Mar-11	Apr-11	May-11
Design Pkg for Fulton Site												
Sign Etoh Takeout Contract												
Sign Feedstock Supply Contract												
Receive Fulton Permits												
Complete FEL-3 Pkg												
Sign EPC Fulton												

### *Data Analysis*

The Phase I tasks were designed to incorporate the expected work to achieve a financeable project ready for financing and the start of construction. Although unforeseen circumstances led to site changes, funds were conserved by focusing on work that is not site specific until site control issues were resolved – ie. process engineering vs. environmental permitting. Work developed in this phase positioned the project to be prepared for plant construction under Phase 2. These included:

- Execution of a long term site lease
- Execution of long term purchase and sale agreement for ethanol produced from the Project
- Execution of a long term biomass supply agreement
- Completion of a Commercial Scale-up Program leading to commercial vendor quotes and vendor confidence in the process
- Completion of FEL-3 Package

In addition, important findings that will benefit the successful commercialization of the Project were obtained from work in this phase of the award. These were in the following areas:

Feedstock Composition and expectation of process yields – A laboratory analysis program that utilized state of the art FTIR analysis of multiple feedstock samples at low cost (~\$100/sample) allowed the construction of a feedstock sourcing program. This program analyzed a variety of

feedstocks by composition, availability, price, ESIA feedstock definition compliance and sizing. The data was fed into a Monte-Carlo simulation program (Crystal Ball®) that came up with the expected high confidence composition, size, cost, ethanol conversion and plant output with better understanding of the variance in these numbers for better proforma financial prediction. Understanding of expected moisture contents, ESIA compliance for RIN credits and tornado analysis were all helpful in developing pro-formas to determine economic viability of projects.

Conversion Technology – Despite the substantial hours spent in pilot plant testing of feedstock and equipment performance and inter-relationship (integration), we found that one of the biggest gaps to overcome were new EPC training and vendor selection to overcome the predicted scaleup barriers. A Commercial Scaleup Program (CSP) was devised to improve the EPC process understanding by incorporating their personnel in the linear pilot testing as well as utilizing vendor pilot equipment they were comfortable scaling from. The net result was a team trained to be cognizant of the process fluid properties and equipment necessities as well as vendors willing to provide performance guarantees beyond typical 10:1 scaleup, in fact up to 600:1 scaleup of some components.

Product Recovery – Part of the CSP was the continuation of microbial strain development based upon the newer technologies developed since the original pilot plant testing was performed. Quickly overturned were the notions that wild or environmentally enhanced microbes could not metabolize mixed cellulosic sugars. Strains related to Sc were identified that could metabolize C6 and C5 sugars simultaneously and within the continuous fermentation timeframe (<10hrs) planned to yield 100% conversion of C6 and up to 40% conversion of C5 sugars. Although final strain results did not yield any patentable microbe by DNA, we were able to license another strain with the same characteristics that was unique for the project. This investigation also provided a detailed understanding of the typical cellulosic nutrients present in the process hydrolysate and those nutrients necessary as additives for fermentation.

Process Requirements – Perhaps the most important work product produced for the advancement of the commercial process technology was the Process Definition Package (PDP). BlueFire Renewables had already produced Heat and Material Balance modeling software, cost estimating software and financial proforma prediction model software, but the transfer of process execution plans had to be established with a work product. A package of reusable base documents including data sheets, specifications and drawings was created that consisted of:

- 32 Process Flow Diagrams
  - 113 Process and Instrumentation Diagrams
  - 154 Major Equipment Specifications
  - 183 Data Sheets
  - 37 Typical Layout Drawings
  - 41 Electrical Drawings
  - 25 Building Layout Drawings
  - 21 Four Inch Binders of Equipment Bids, Cost Estimates, Execution Program Documents, Quality Documents. Etc.
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Permits and Contracts – A necessary part of constructing a cellulosic plant is financing it, and an integral part of financing a plant is obtaining permits and other contracts. While virtually every regulatory agency and entity providing or obtaining plant permits or services is different and has different regulatory reviews for their approvals or contracts, having a proven starting point is a big advantage. Under Phase 1, BlueFire was able to demonstrate the permissibility of its process under all regulatory levels including; Clean Air Act, Clean Water Act, and the National Environmental Protection Act. The key approvals completed in Phase 1 include: Air, Water, Discharge, Safety Storage, Environmental Assessment under NEPA, and Army Corps of Engineers. Information gathered under these proceedings will be very helpful in the development of subsequent projects

Financing requires that inputs and outputs to the process are secured from credit-worthy companies and available on a long term basis for the life of the plant. Although analysis of feedstock availability in the area revealed robust supplies for the Project, a qualified entity must be found that could insure there are no disruptions in the delivery of material. Likewise, despite the fact that mandated demand under the Federal Renewable Fuel Standards for cellulosic ethanol far outstrips supplies, investors must be satisfied that a qualified credit-worthy party would be there to insure distribution and sale of the ethanol product. In both cases, long term contracts were signed with credit worthy entities under this phase of the award.

Another critical element for financing is an EPC contract. This is particularly difficult to obtain for first of a kind implementation of an emerging technology with boundaries for cost and penalties for performance. Under this phase of the award, through the work with engineers and equipment suppliers that have been involved in the evolution of the process design, we were able to obtain an EPC contract that is workable to effect financing of the project.

The know-how and templates created for the feedstock and off-take negotiations are invaluable tools that would be useful in subsequent projects and could be easily adaptable for feedstock sources that are urban or rural related. Specialized equipment bid packages including procurement boiler plate and quality assurance documents created for this project would also be useful for future projects.

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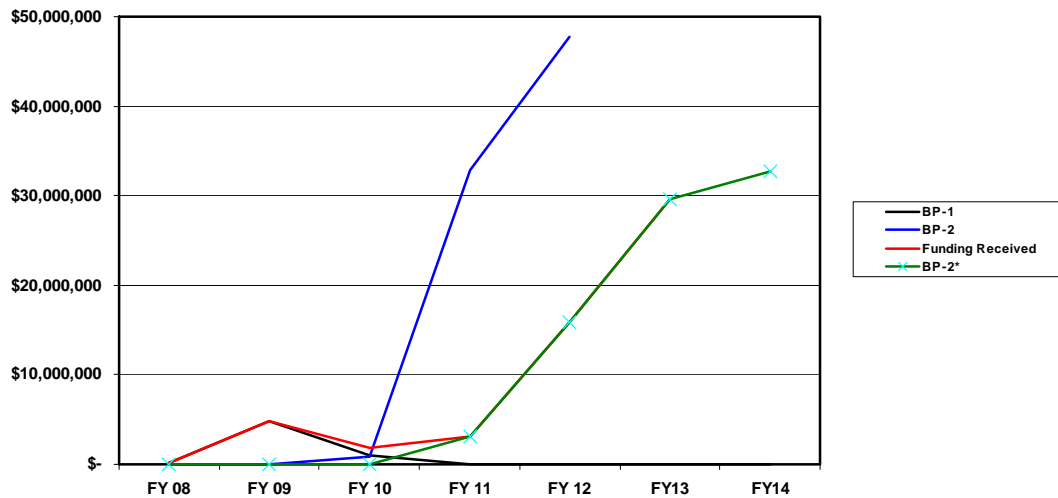
## Project schedule, budget: planned versus actual

### *Project Schedule & Budget*

The Phase I and remaining Phase II Budget can best be summarized as follows:

	Award 1	Award 2 (ARRA)	Total
DOE Share	\$ 6,425,564	\$ 81,134,686	\$ 87,560,250
BF Cost Share	\$ 14,028,504	\$ 232,185,496	\$ 246,214,000
DOE Funds Received	\$ 6,059,936	\$ 3,158,007	\$ 9,217,943
DOE Funds Unspent	\$ 365,628	\$ 77,976,679	\$ 78,342,307

Due to delays in completing the financing of the project, the expected budget cash flow against the originally planned baseline is represented below:

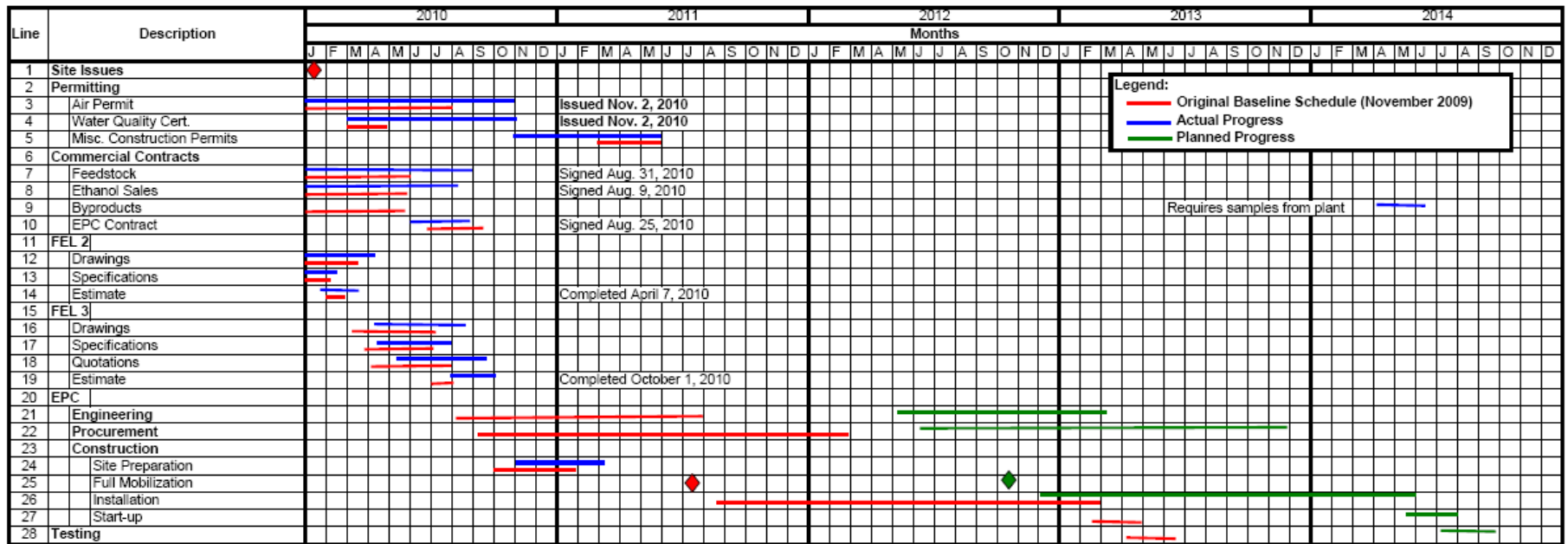


A summary of the project schedule is shown below, although subject to change depending on the financial closure date.





BlueFire Fulton  
Level - 1 Project Execution Schedule



## Major Lessons Learned

### **Feedstock considerations is a major consideration for project implementation**

Feedstock handling from fuel cost, location, fuel handling, reliability and dependability, and partnerships are factors critical to the success of the Project. Work with various equipment vendors, sampling of a multitude of expected feedstock supplies and monte-carlo simulations have allowed us to gain important knowledge to identify potential risks and to address those in the design and development of the Project. These lessons with the experience learned from construction and operation will be significant for biomass fuels and chemicals to become cost-effective, main stream alternatives.

### **Financing structures for a renewable power plant is not readily adaptable to a renewable fuel plant**

While the Federal RFS is a primary driver for the commercialization of cellulosic ethanol, the significant demand vs available supply is not in itself sufficient to overcome the offtake risk viewed by investors. Pricing of ethanol is subject to commodity risk unlike renewable power where 20 plus year power purchase agreements with pricing visibility make lenders more comfortable. While there is cellulosic premiums through the RIN system, that structure is still unproven and its market dynamics, untested. Going forward, the long term stability of the RFS program is important to ensure that there would be a market for the ethanol fuel. The off-take contract completed in this phase of the DOE award is helpful with respect to having a credit-worthy entity that will take responsibility for the distribution and sale of the ethanol but price hedging mechanisms are likely to be required to assuage lenders of the certainty in expected Project revenues.

### **Use of proven technology, adaptation of commercial equipment and demonstration of process conditions at multiple levels help to mitigate technology risks**

The concentrated acid hydrolysis process that will be employed in the Project is essentially an improvement of a technology first used in 1898. Extensive work demonstrated in multiple pilot facilities by the licensor, Arkenol, a third party, and in this phase, commercial equipment vendors produced results that are consistent. Use of commercial equipment used in other industries and involvement of these suppliers in the evolution of the technology established confidence in quoting specific equipment for the desired plant. All work thus far has tried to identify as much of the potential process pitfalls that could be identified at this point in time. Anything more can only be identified during the construction and operation of the plant for which contingencies, fund reserves, robust operating budgets, and insurance products are proposed to overcome financing concerns.

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